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Measurement of linear energy transfer spectra of high-LET space radiation inside the International Space Station modules (2013-2014)

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Abstract

The field of space radiation in low-Earth orbit is extremely complicated due to many reasons. It is formed mainly of galactic cosmic rays (GCR), solar particles and trapped particles in the south Atlantic anomaly region. In addition radiation field is affected by shielding and scattering of incident primary particles by surrounding material. The contribution of short – range particles produced in the nuclear interactions in the shielding and contents of the spacecraft to the total radiation field is comparable to the primary component at high values of dE/dx.
Preliminary linear energy transfer (LET) spectra of high-LET space radiation were measured in different compartments of the Russian segment of International Space Station (ISS) by means of plastic nuclear track detectors (PNTD) CR-39 TASTRACK. Measurements were carried out during ISS-37/38/39 expeditions in MATROSHKA-R space experiment. The comparison of experimental spectra with simulated one was made in order of data verification.

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*Keywords:*CR-39; solid-state nuclear track detector; high-LET space radiation; International Space Station; MATROSHKA-R; passive detectors; long term space flight; low-Earth orbit; space radiation environment;

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1. Introduction

Measurements of high-LET space radiation in long term space flights are important for radiobiological values estimation and can be used for radiation hazards to astronaut's estimation and verification of space radiation environment models [3, 4, 6, 8, 10, 12].

The aim of this study was space radiation LET spectra measurements inside various compartments of Russian segment of International Space Station by means of etched track detectors CR-39 TASTRAK in complex long term space experiment MATROSHKA-R [1, 5, 7, 9] 2013-2014 session.

2. Position of detectors and flight conditions

Etched track detectors were packed in 6 Passive Detectors Assembles boxes "SPD" (boxes No. A 101-A 106). Positions of boxes are shown in Table 1. The location of SPD box 2 was changed since previous sessions of measurements [1] and [7]. The new position was selected in Small Research Module 2 instead of Piers module.

Table 1.Locations of SPD boxes.

SPD box	Panel, position
SPD A 101	102 Piers Module 1, floor
SPD A 102	102 Small Research Module 2, floor
SPD A 103	325 SM, cone, ceiling, close to R-16
SPD A 104	461 SM, the star board
SPD A 105	323 SM, cone, ceiling, close to R-16
SPD A 106	305 SM, ceiling, small diameter

Time interval of the exposure (26 September 2013 – 13 May 2014) corresponded to the 24^{th} solar activity cycle growing. The ISS orbital parameters variations in 2013-2014 year appeared to be low. Averaged apogee was 435 km, perigee – 415 km and inclination – 51.67º.

3. Methodology and detector processing

The etched track detectors CR-39 TASTRAK of 1 mm thickness and surface square 3x3 cm^2 were applied in the experiment. The two step chemical etching technique was used for detectors treatment [6]. They were etched in 6N NaOH solution at 70º C during 6 and 15 hours [14]. Corresponding bulk etch was 8.1 and 20.25 um respectively.

After each step of etching the detectors surfaces were scanned on the track analyzing system based on microscope Carl Zeiss AxioScoupe.A1 in 2-D and 3-D scanning modes and the track observable parameters were measured. Tracks with ranges R>8 um and R≥20 um in CR-39 were selected after 6 h and 15 h etching time respectively. Tracks of HZE particles were measured after 6 h etching time in the course of special scanning. Total differential LET spectra were compiled from spectral data, obtained after two stages of detectors processing.

In 2-D mode scanning the sensitivity of detector was evaluated via track pit diameters and in 3-D mode scanning it was evaluated via track cone length [11]. For calculation of LET value the international calibration curve for CR-39 TASTRAK detector was used [14].

The detector threshold turned out to be 15 keV/um (H_2O) approximately. This value is in good agreement with results obtained previously in [5] and [6].

Track data processing was made with help of specially developed MatLab code. Model LET spectrum in tissue was calculated with help of OLTARIS tool [13] with the use of parameters shown in Table2.

Table 2.Parameters used in simulation LET spectra.

Environmenttype	Earth Orbit (Altitude = 425.0 km; Inclination = 51.67 degrees)
Components	GCR -Yes, Trapped Protons –Yes, Neutron Albedo - No
GCR model	Badhwar-O'Neil 2010
Sphere geometry	Al sphere, 40 g/cm^2 thickness

The spectrum was calculated for the period 26-30 September 2013.

4. Results and discussion

The measured differential LET spectra in various locations of SPD boxes and calculated differential LET spectrum are shown in Fig.1.

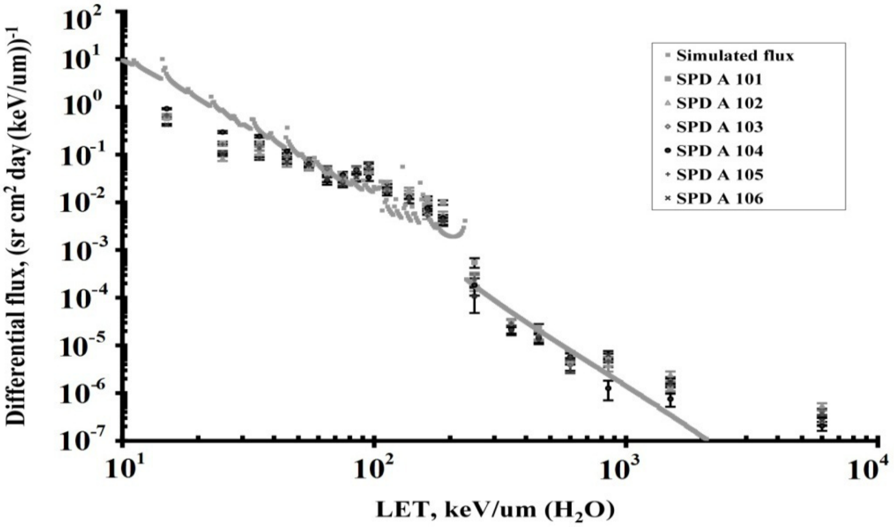

Fig. 1.Comparison of experimental and calculated differential LET spectra inside the ISS

It can be seen from Fig.1 that experimental data are in good agreement with simulated one in the LET range from 35 to 850 keV/um. Deviation in the LET>850 keV/um can be explained by the absence of calibration data in this region [14]. The deviation in the low LET region is possibly due to the low detector sensitivity near threshold [5], [6]. That's why some tracks with LET<35 keV/um could be missed during scanning [2]. The second reason of deviation is caused by uncertainties of averaged shielding thickness estimation [7]. In the case of higher shielding thickness the proton flux should be significantly lower.

All measured spectral data shows small deviations in different shielding conditions. This conclusion is in good correlation with previous results of MATROSHKA-R experiment sessions in 2007 and 2009 [1].

5. Conclusions

Further efforts will be focused on enhancement of short range particle tracks scanning technique and calibration of detectors in range of 250-1500 keV/um. Also the MatLab code for track data processing will be modified.

The data obtained will be used for radiation risk estimations, for total doses and averaged quality factors estimation and for investigation flux of HZE particles onboard ISS. Also the data will be compared with new results of MATROSHKA-R experiment which are expected in 2016.

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